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PTO/SB/05 (2/98)

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No	TI-29648
First Named Inventor or Application Identifier	Srinath Hosur
Title	Spread Spectrum Multipath Combination
Express Mail Label No.	EL547747085US

On Page 1 of the specification, before line 1, insert –This application claims priority under 35 USC § 119(e)(1) of provisional application number **60/152,974** filed **09/09/1999**.--

APPLICATION ELEMENTS

See MPEP Chapter 600 concerning utility patent application contents

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [X] *Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original, and a duplicate for fee processing)*
2. [X] Specification [Total Pages 15] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R&D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) *(35 USC d113)* [Total Sheets 5]
4. Oath or Declaration [Total Pages]
   a. [ ] Newly Executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR §1.63(d)) *(for continuation/divisional with Box 17 completed)*

   [Note Box 5 below]

   i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR §1.63(d)(2) and 1.33(b).
5. [ ] Incorporation By Reference *(useable if Box 4b is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identical of above copies

ACCOMPANYING APPLICATION PARTS

8. [ ] Assignment Papers (cover sheet & Documents(s))
9. [ ] 37 CFR §3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
10. [ ] English Translation Document *(if applicable)*
11. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
12. [ ] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. [ ] *Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application Status still proper and desired
15. [ ] Certified Copy of Priority Document(s) *if foreign priority is claimed)*
16. [ ] Other:

*A new statement is required to be entitled to pay small entity fees, except where one has been filed in a prior application and is being relied upon.

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information below and in a preliminary amendment:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: / .

Prior application information: ***Examiner*** _____ ***Group / Art Unit:*** _____

18. CORRESPONDENCE ADDRESS

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Signature		Date	9/8/00

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09/08/00 JC690 U.S. PTO
09/08/00 JC905 U.S. PTO 09/659431

PTO/SB/17 (1/98)

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DATE: **09/08/2000**

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1.
These are the fees effective October 1, 1997
Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12.

TOTAL AMOUNT OF PAYMENT	($) $690

Complete If Known	
Application Number	
Filing Date	09/08/2000
First Named Inventor	Srinath Hosur
Examiner Name	
Group / Art Unit	
Attorney Docket No.	TI-29648

METHOD OF PAYMENT

1. ☒ The Commissioner is hereby authorized to charge to the following Deposit Account,

Deposit Account Number: **20-0668**

Deposit Account Name: **Texas Instruments Incorporated**

☒ Charge any additional fee required or credit any overpayment

☐ Charge all indicated fees and any additional fee required or credit any overpayment

2. ☐ **Payment Enclosed:**

☐ Check ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Fee Code	Entity Fee ($)	Small Fee Code	Entity Fee ($)	Fee Description	Fee Paid
101	790	201	395	Utility filing fee	$690
106	330	206	165	Design filing fee	
107	540	207	270	Plant filing fee	
108	790	208	395	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 690

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	9	-20**=	0	x	18	=	$00
Independent Claims	3	-3** =	0	x	78	=	$00
Multiple Dependent						=	$00

**or number previously paid, if greater; For Reissue, see below

Large Fee Code	Entity Fee ($)	Small Fee Code	Entity Fee ($)	Fee Description
103	18	203	11	Claims in excess of 20
102	78	202	41	Independent Claims in excess of 3
104	270	204	135	Multiple dependent claims in excess of 3
109	82	209	41	**Reissue independent claims over original patent
110	22	210	11	**Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) $00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Fee Code	Entity Fee ($)	Small Fee Code	Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension of time within second month	
117	950	217	475	Extension of time within third month	
118	1,510	218	755	Extension of time within fourth month	
128	2,060	228	1,030	Extension of time within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a pubic use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,320	241	660	Petition to revive - unintentional	
142	1,320	242	660	Utility issue fee (or reissue)	
143	450	243	225	Design issue fee	
144	670	244	335	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt.	
581	40	581	40	Recording each patent assignment per property (time number of properties)	
146	790	246	395	Filing a submission after final rejection (37 CFR 1 129(a))	
149	790	249	395	For each additional invention to be examined (37 CFR 1.129(b))	

Other fee (specify) _____

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3)

SUBMITTED BY		Complete (if applicable)	
Typed or Printed Name	Carlton H. Hoel	Reg Number	29,934
Signature		Date 9/8/00	Deposit Account User ID

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SPREAD SPECTRUM MULTIPATH COMBINATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from provisional application Serial No. 60/152,974, filed 09/09/99. The following patent applications disclose related subject matter: Serial Nos. 08/....., filed .... (TI-----). These applications have a common assignee with the present application.

BACKGROUND OF THE INVENTION

The present invention relates to digital communications, and more particularly to multipath received signal combination systems and methods.

Spread spectrum wireless communications utilize a radio frequency bandwidth greater than the minimum bandwidth required for the transmitted data rate, but many users may simultaneously occupy the bandwidth. Each of the users has a pseudo-random code for "spreading" information to encode it and for "despreading" (by correlation) received spread spectrum signals and recovery of information. Figure 2 shows a system block diagram, and Figure 3 illustrates a QPSK (quadrature phase-shift keying) encoder with pseudo-noise spreading. Such multiple access typically appears under the name of code division multiple access (CDMA). The pseudo-random code may be an orthogonal (Walsh) code, a pseudo-noise (PN) code, a Gold code, or combinations (modulo-2 additions) of such codes. After despreading the received signal at the correct time instant, the user recovers the corresponding information while other users' interfering signals appear noise-like. For example, the interim standard IS-95 for such CDMA communications employs channels of 1.25 MHz bandwidth and a pseudo-random code pulse (chip) interval T_c of 0.8138 microsecond with a transmitted symbol (bit) lasting 64 chips. The recent wideband CDMA (WCDMA) proposal employs a 3.84 MHz bandwidth and the CDMA code length applied to

each information symbol may vary from 4 chips to 256 chips. Indeed, UMTS (universal mobile telecommunications system) approach UTRA (UMTS terrestrial radio access) provides a spread spectrum cellular air interface with both FDD (frequency division duplex) and TDD (time division duplex) modes of operation. UTRA currently employs 10 ms duration frames partitioned into 15 time slots with each time slot consisting of 2560 chips (T_C = 0.26 microsecond).

The CDMA code for each user is typically produced as the modulo-2 addition of a Walsh code with a pseudo-random code (two pseudo-random codes for QPSK modulation) to improve the noise-like nature of the resulting signal. A cellular system as illustrated in Figure 4 could employ IS-95 or WCDMA for the air interface between the base station and the mobile user station.

A spread spectrum receiver synchronizes with the transmitter by code acquisition followed by code tracking. Code acquisition performs an initial search to bring the phase of the receiver's local code generator to within typically a half chip of the transmitter's, and code tracking maintains fine alignment of chip boundaries of the incoming and locally generated codes. Conventional code tracking utilizes a delay-lock loop (DLL) or a tau-dither loop (TDL), both of which are based on the well-known early-late gate principle.

The air interface leads to multipath reception, so a RAKE receiver has individual demodulators (fingers) tracking separate paths and combines the finger results to improve signal-to-noise ratio (SNR). The combining may use a method such as the maximal ratio combining (MRC) in which the individual detected signals in the fingers are synchronized and weighted according to their signal strengths or SNRs and summed to provide the decoding statistic as illustrated in Figures 5a-5b. That is, a RAKE receiver typically has a number of DLL or TDL code tracking loops together with control circuitry for assigning tracking units to the strongest received paths. Also, an antenna array could be

used for directionality by phasing the combined signals from the antennas.

However, known multipath combination methods have problems including robustness.

SUMMARY OF THE INVENTION

The present invention provides a multipath received signal combination covariance matrix eigenvector components used for relative path weightings. Linear approximations of channel response provide models for covariance matrix analysis.

This has the advantages of a robust maximal ratio combination. Also the technique can be blind; that is, it does not require pilot symbols.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings are heuristic for clarity.

Figures 1a-1c show a preferred embodiment detector, linear approximation, and flow diagram for multipath combining.

Figure 2 shows a CDMA communications in block diagram.

Figure 3 illustrates a.CDMA encoder.

Figure 4 indicates cellular communications.

Figures 5a-5b illustrate RAKE receiver fingers and antenna array.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Overview

Preferred embodiment spread spectrum communications systems use preferred embodiment blind (without synchronization) maximal ratio combining (MRC) methods with multipath detectors. Preferred embodiment MRC methods estimate time varying multipath channels using eigenvectors associated with maximal eigenvalues of matrices correlating individual path outputs. Local linear approximations of channel parameter variation over time simplify the matrix analysis. Figure 1a illustrates a preferred embodiment RAKE detector which may apply the preferred embodiment MRC methods. Figure 1b suggests the channel parameter linear approximation, and Figure 1c is a flow diagram. In contrast, the known MRC methods estimate each path separately and then combine with weightings proportional to path output power.

The preferred embodiment MRC methods include updating channel estimates both on a symbol-by-symbol basis and on a slot (sequence of symbols) basis. For an updating on a symbol-by-symbol basis, the path covariance analysis averages over output sequences from each path where the output sequences have length 4K+1 and are centered about the symbol interval for updating; thus each updating requires new covariance matrices. Typically, for WCDMA take K in the range of roughly 20 to 40, depending upon the Doppler rate and the symbol rate (32 KSPS channel). For an updating on a slot basis, the channel estimates for all of the 4K+1 symbol intervals in the slot derive from the a single set of covariance matrices over the length 4K+1 output sequences. This amounts to a linear approximation of the channel over the slot.

Interim standard IS-95 and wideband CDMA (WCDMA) proposals include a pilot signal which is much stronger than the data signals and can be used for preferred embodiment overall channel estimation.

In preferred embodiment communications systems base stations and mobile users could each include one or more digital signal processors (DSP's) and/or other programmable devices with stored programs for performance of the signal processing of the preferred embodiment synchronization methods. Alternatively, specialized circuitry could be used. The base stations and mobile users may also contain analog integrated circuits for amplification of inputs to or outputs from antennas and conversion between analog and digital; and these analog and processor circuits may be integrated on a single die.. The stored programs may, for example, be in ROM or flash EEPROM integrated with the processor or external. The antennas may be parts of receivers with multiple finger RAKE detectors for each user's signals. Exemplary DSP cores could be in the TMS320C6x or TMS320C5x families from Texas Instruments.

Symbol-by-symbol update preferred embodiments

Preferred embodiments estimate the multiple paths of a received signal and perform MRC for detection of a transmitted symbol s(0) from a sequence of transmitted symbols s(k). The received baseband signal at a RAKE detector can be expressed as the real part of

$$r(t) = \sum_k \sum_m h_m(k)\, s(k)\, c(t-kT-\tau_m(k)) + \text{noise}(t)$$

where T denotes the time interval of a symbol, c() denotes the pseudo-random code of values ± 1 (and equals 0 outside of the interval [0,T]), and m indexes the multipath with relative delay $\tau_m(k)$ and channel gain and phase $h_m(k)$ during symbol s(k) propagation. Presume normalized symbols: $|s(k)|^2 = 1$. Each RAKE detector finger tracks and despreads (correlates) one of the multipaths using c() to despread and synchronize. Let $y_m(k) = h_m(k)\, s(k) + v_m(k)$ denote the mth finger output where $v_m(k)$ models noise along the mth path. Indeed, take the $v_m(k)$ to be independent, normally distributed, and with standard deviation σ. Then MRC weights the outputs $y_m(k)$ according to their power and phase, so

ideally the MRC weightings are proportional to $h_m(k)^*$ and the MRC decoding statistic with θ the overall phase would be

$$e^{\iota\theta} \sum_m y_m(k)h_m(k)^*$$

The expectation of $y_m(k)$ over a sequence of ks is approximately 0 because s(k) is randomly $\pm 1, \pm j$ (assuming QPSK modulation) and varies more rapidly than $h_m(k)$; thus consider the MxM covariance matrix **C** of the synchronized finger outputs with components given by

$$C_{m,n} = (\sum_k y_m(k)y_n(k)^*)/(4K+1)$$

where the k sum is over the range $-2K \le k \le 2K$ with K on the order of 20 to 40. Expressed in matrix form with **y**(k) the M-dimensional vector of synchronized outputs and $(.)^H$ denoting Hermitian conjugate (adjoint):

$$\mathbf{C} = \sum_k \mathbf{y}(k)\mathbf{y}^H(k)/(4K+1)$$

Locally, $h_m(k)$ can be reasonably approximated by low order polynomials in k. Thus consider constant and linear approximations.

1. First consider a time-invariant channel; that is, take $h_m(k) = h_m$ for all k in the range –2K to 2K. With this presumption and using the fact that s(k) is randomly $\pm 1, \pm j$, the covariance matrix then becomes:

$$\mathbf{C} = \mathbf{h}\mathbf{h}^H + \sigma^2\mathbf{I}$$

where **h** is the M-component vector with mth component equal to h_m. This essentially is a spectral resolution for **C** and shows that **C** has one eigenvalue equal to $|\mathbf{h}|^2 + \sigma^2$ which is associated with the normalized eigenvector $\mathbf{h}/|\mathbf{h}|$ plus an (M-1)-order eigenvalue equal to σ^2 which is associated with M-1 (generalized) eigenvectors orthogonal to **h**. Thus the preferred embodiment proceeds as follows:

(1) form covariance matrix **C** as averages over sequences of finger outputs.

(2) find λ_{MAX}, the largest eigenvalue of **C**, and its associated normalized

eigenvector, **w**, and

(3) define the MRC (up to an overall phase) decoding statistic to be

$$\sum_m w^*_m y_m(0)$$

(4) determine the overall phase of this MRC statistic by any channel estimation method, such as taking fourth powers to eliminate the symbol phase (presumed QPSK modulation) and using a phase-locked loop.

(5) decode the symbol s(0) from the resultant phase-adjusted MRC statistic.

2. Next, consider the case of **h**(k) varying linearly with time. In particular, presume that for k in the range -2K to 2K:

$$\mathbf{h}(k) = \alpha + k\beta$$

where α and β are (unknown) constant M-dimensional vectors. Figure 1b heuristically illustrates the approximation for a component $h_m(k)$ with the broken horizontal line representing α_m and the slope of the diagonal line β_m. So approximate **h**(k) and thereby determine the MRC weightings from estimates for α and β. Thus first define covariance matrices $\mathbf{C}_0$ and $\mathbf{C}_1$ as the sums over the k intervals $-K \le k \le -1$ plus $1 \le k \le K$ and $-2K \le k \le -(K+1)$ plus $K+1 \le k \le 2K$, respectively:

$$\mathbf{C}_0 = \sum_{\pm k=1,K} \mathbf{y}(k)\mathbf{y}^H(k)/2K$$

$$\mathbf{C}_1 = \sum_{\pm k=K+1,2K} \mathbf{y}(k)\mathbf{y}^H(k)/2K$$

Figure 1b illustrates the two portions of the –2K to 2K symbol interval slot used to define the two covariance matrices. Then invoking the presumed linear form of **h**(k) yields:

$$\mathbf{C}_0 = \alpha\alpha^H + f_0(K)\,\beta\beta^H + \Gamma_0 + \Psi_0$$

$$\mathbf{C}_1 = \alpha\alpha^H + f_1(K)\,\beta\beta^H + \Gamma_1 + \Psi_1$$

where $f_0(K) = (2K^2+3K+1)/6$ and $f_1(K) = (14K^2+9K+1)/6$ are the corresponding sums of k^2 over the two k ranges, each divided by 2K, and the noise terms Γ_0,

Ψ_0, Γ_1, and Ψ_1 arise from the y(k)-noise cross terms and noise squared terms in the two sums of $\mathbf{y}(k)\mathbf{y}^H(k)$ over k. These variables have the following properties: mean(Γ_0) = mean(Γ_1) = 0; mean(Ψ_0) = mean(Ψ_1) = 0; var(Γ_0) = var(Γ_1) = $\sigma^2||\alpha||^2\mathbf{I}/2K$; and var($\Psi_0$) = var($\Psi_1$) = $\sigma^2\mathbf{I}/2K$; thus consistent estimates can be obtained.

Estimate α and β essentially by ignoring the noise terms in the foregoing pair of linear equations and solving for $\alpha\alpha^H$ and $\beta\beta^H$ followed by eigenvector analysis. In particular, first define the estimates

$$\mathbf{A} = (f_1(K)\,\mathbf{C}_0 - f_0(K)\,\mathbf{C}_1)/(f_1(K) - f_0(K))$$

$$\mathbf{B} = (-\mathbf{C}_0 + \mathbf{C}_1)/(f_1(K) - f_0(K))$$

Thus **A** estimates $\alpha\alpha^H$ + noise terms and **B** estimates $\beta\beta^H$ + noise terms. As previously described, the largest eigenvalue of **A** equals $||\alpha||^2$ + noise variance and has a corresponding normalized eigenvector which estimates $\alpha/||\alpha||$ up to an overall phase. Similarly, the largest eigenvalue of **B** equals $||\beta||^2$ + noise variance and has a corresponding normalized eigenvector which estimates $\beta/||\beta||$ up to an overall phase.

In short, the preferred embodiment method of MRC for symbol s(0) uses the linearized model of **h**(k) and includes the following steps:

(1) compute the covariance matrices $\mathbf{C}_0$ and $\mathbf{C}_1$ from the vector **y**(k) of synchronized detected RAKE finger signals for symbol index k in the range -2K to 2K; k = 0 corresponds to the symbol of interest for the MRC. That is,

$$\mathbf{C}_0 = \sum_{\pm k=1,K} \mathbf{y}(k)\mathbf{y}^H(k)/2K$$

$$\mathbf{C}_1 = \sum_{\pm k=K+1,2K} \mathbf{y}(k)\mathbf{y}^H(k)/2K$$

(2) generate the estimate **A** from the covariance matrices $\mathbf{C}_0$ and $\mathbf{C}_1$ by

$$\mathbf{A} = (f_1(K)\,\mathbf{C}_0 - f_0(K)\,\mathbf{C}_1)/(f_1(K) - f_0(K))$$

where $f_0(K) = (2K^2+3K+1)/6$ and $f_1(K) = (14K^2+9K+1)/6$.

(3) find the largest eigenvalue, λ_A, and corresponding normalized

eigenvector, $\mathbf{w}_A$, of the estimate **A**.

(4) define the MRC (up to an overall phase) decoding statistic to be

$$\sum_m w^*_{A,m} y_m(0)$$

(5) determine the overall phase of this MRC statistic by any channel estimation method, and

(6) decode the symbol s(0) from the resultant phase-adjusted MRC statistic.

Update per slot preferred embodiments

The preferred embodiment method of MRC for all ks in a slot of k values from -2K to +2K (such as illustrated in Figure 1b) again uses the linearized model of **h**(k) and includes the following steps:

(1) compute the covariance matrices $\mathbf{C}_0$ and $\mathbf{C}_1$ from the vector **y**(k) of synchronized detected RAKE finger signals for symbol index k in the range -2K to +2K. That is,

$$\mathbf{C}_0 = \sum_{\pm k=1,K} \mathbf{y}(k)\mathbf{y}^H(k)/2K$$

$$\mathbf{C}_1 = \sum_{\pm k=K+1,2K} \mathbf{y}(k)\mathbf{y}^H(k)/2K$$

(2) generate the estimates **A** and **B** from the covariance matrices $\mathbf{C}_0$ and $\mathbf{C}_1$ by

$$\mathbf{A} = (f_1(K)\,\mathbf{C}_0 - f_0(K)\,\mathbf{C}_1)/(f_1(K) - f_0(K))$$

$$\mathbf{B} = (-\mathbf{C}_0 + \mathbf{C}_1)/(f_1(K) - f_0(K))$$

where $f_0(K) = (2K^2+3K+1)/6$ and $f_1(K) = (14K^2+9K+1)/6$.

(3) find the largest eigenvalues, λ_A and λ_B, and corresponding normalized eigenvectors, $\mathbf{w}_A$ and $\mathbf{w}_B$, of **A** and **B**, respectively. The eigenvalues are real due to all of the matrices $\mathbf{y}(k)\mathbf{y}^H(k)$ being Hermitian.

(4) estimate the channel for k in the slot as $\mathbf{h}'(k) = \sqrt{\lambda_A}\,\mathbf{w}_A + k\sqrt{\lambda_B}\,\mathbf{w}_B$. Because $\mathbf{w}_A$ and $\mathbf{w}_B$ are only determined up to a phase, use the k=0 case as previously described to determine the overall phase for $\mathbf{w}_A$. When s(k) is QPSK,

we can compute $\sum_{\pm k=1,K} (\mathbf{y}^T(k)\mathbf{y}(k))^2/2K$ and $\sum_{\pm k=K+1,2K} (\mathbf{y}^T(k)\mathbf{y}(k))^2/2K$. The expressions obtained will be functions of $\mathbf{w}_A{}^T\mathbf{w}_A$, $\mathbf{w}_B{}^T\mathbf{w}_B$, λ_A, λ_B and the residual phases on $\mathbf{w}_A$ and $\mathbf{w}_B$. The residual phases can be determined from the resulting equations since we know all the other quantities. In case s(k) is BPSK we only need to use compute $\sum_{\pm k=1,K} \mathbf{y}^T(k)\mathbf{y}(k)/2K$ and $\sum_{\pm k=K+1,2K} \mathbf{y}^T(k)\mathbf{y}(k)/2K$. A combination of this and the phase estimation method for k=0 can also be used to estimate the residual phases. Alternatively, pilots from the transmitter could be used for phase determinations.

(5) use the components of $\mathbf{h}'(k)$ for relative weightings in the MRC of $\mathbf{y}(k)$ for each k in the slot (k=0,K was already done in step (4)). That is, take the MRC statistic for each k in the slot to be the sum

$$\sum_m y_m(k)h'_m(k)^*$$

(6) for each k decode the symbol s(k) from the resultant phase-adjusted MRC statistics.

Alternative preferred embodiments

Alternative preferred embodiment quadratic (or higher order) approximations for the channel presume $h_m(k) = \alpha_m + k\beta_m + k^2\gamma_m$ and thus divide the sequence of received symbols into three sections and form three covariance matrices to solve for estimates of $\alpha\alpha^H$, $\beta\beta^H + \alpha\gamma^H + \gamma\alpha^H$, and $\gamma\gamma^H$ followed by eigenvalue and eigenvector analysis to estimate α, β, and γ and thus $\mathbf{h}(k)$ for use in the MRC. Of course, taking k in the interval -3K to 3K makes the notation simpler and there are three coefficient factors $f_0(K)$, $f_1(K)$, and $f_2(K)$ as second order polynomials and three more coefficient factors as fourth order polynomials.

Modifications

The preferred embodiments can be modified in various ways while retaining the features of a finding relatively weightings for multipath combining by

eigenvector components of path covariance matrices.

For example,.instead of updating the MRC coefficients every symbol one can update them every L'th symbol and interpolate or use the same estimates for the symbols in between.

Similarly instead of every slot one can compute every half slot or two slots and interpolate for the values in between.

Other techniques for phase estimation for e.g., decision directed phase estimation.

Other weightings in the multipath combinations could be used; this could involve (fractional) powers of the channel estimation.

CLAIMS (29648)

What is claimed is:

1. A method of multipath combining, comprising:

(a) forming at least one matrix of covariances of multipath inputs;

(b) finding an eigenvector of said matrix; and

(c) combining said multipath inputs relatively weighted according to the components of said eigenvector.

2. The method of claim 1, wherein:

(a) said eigenvector is associated with a maximal eigenvalue of said matrix.

3. The method of claim 1, wherein:

(a) said weightings have magnitudes proportional to the squared magnitudes of said eigenvector components and have phases proportional to the phases of said eigenvector phases.

4. A method of multipath combining, comprising:

(a) forming a first matrix of covariances of multipath inputs over a first range and a second matrix of covariances of multipath inputs over a second range;

(b) forming an estimation matrix from said first and second matrices;

(c) finding an eigenvector of said estimation matrix; and

(c) combining said multipath inputs relatively weighted according to the components of said eigenvector.

5. The method of claim 4, wherein:

(a) said eigenvector is associated with a maximal eigenvalue of said estimation matrix.

6. The method of claim 4, wherein:

(a) said weightings have magnitudes proportional to the squared magnitudes of said eigenvector components and have phases proportional to the phases of said eigenvector phases.

7. The method of claim 4, further comprising:

(a) forming a second estimation matrix from said first and second matrices;

(b) finding a second eigenvector of said second estimation matrix; and

(c) wherein said combining said multipath inputs relatively weighted according to the components of said eigenvector includes relatively weighted also according to the components of said second eigenvector.

8. A multipath receiver, comprising:

(a) a plurality of detectors, each detector detecting a path of a multipath input;

(b) first circuitry coupled to said detectors and connected to form a first matrix of covariances of outputs of said detectors over a first range and a second matrix of covariances of outputs of said detectors over a second range;

(c) second circuitry coupled to said first circuitry and connected to form an estimation matrix from said first and second matrices;

(c) third circuitry coupled to said second circuitry and connected to find an eigenvector of said estimation matrix; and

(c) fourth circuitry coupled to said third circuitry and connected to combine

said outputs relatively weighted according to the components of said eigenvector.

9. The receiver of claim 8, wherein:

(a) said first, second, third, and fourth circuitry include a programmed processor.

ABSTRACT OF THE DISCLOSURE

Multipath relative channel estimations for weighting maximal ratio combining of RAKE detectors in wireless communication systems uses maximal eigenvectors of covariance matrices of path signals. Estimates for close-in and outlying sets of symbols provides linear time change channel estimation.

Figure 1a

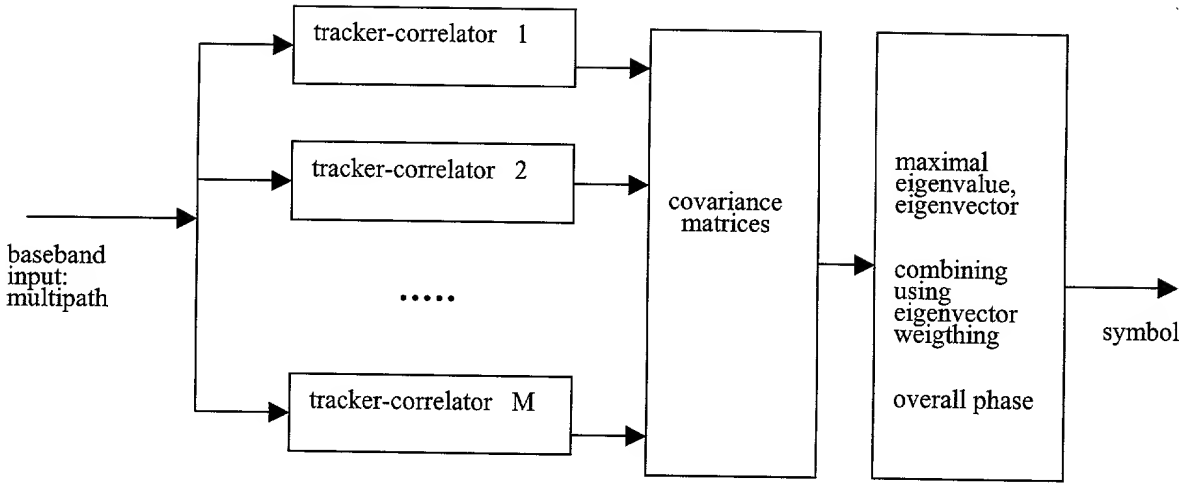


Figure 1b

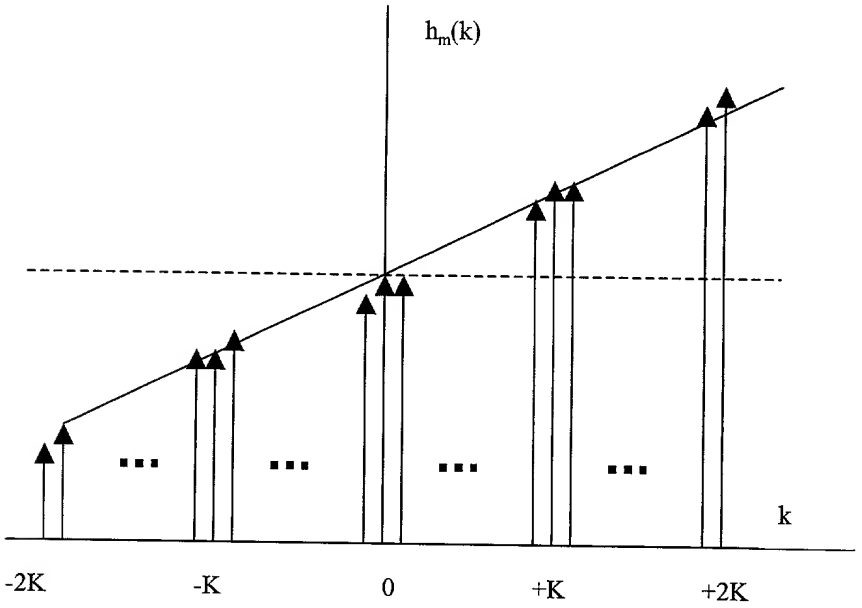
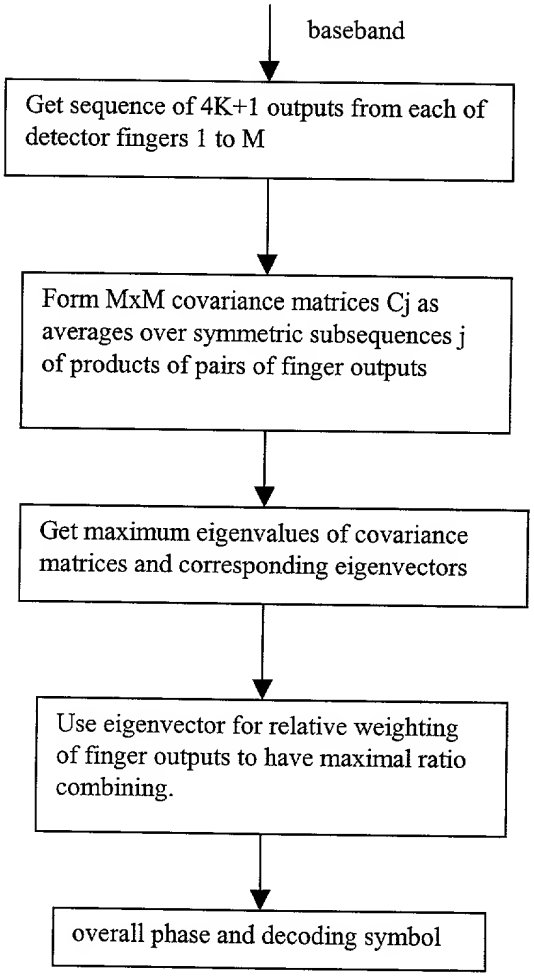


Figure 1c


baseband
Get sequence of 4K+1 outputs from each of detector fingers 1 to M
Form MxM covariance matrices Cj as averages over symmetric subsequences j of products of pairs of finger outputs
Get maximum eigenvalues of covariance matrices and corresponding eigenvectors
Use eigenvector for relative weighting of finger outputs to have maximal ratio combining.
overall phase and decoding symbol

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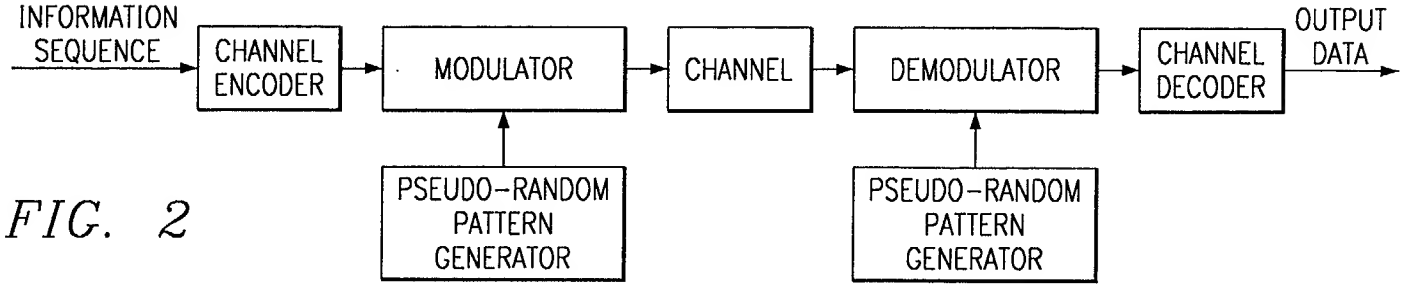

FIG. 2

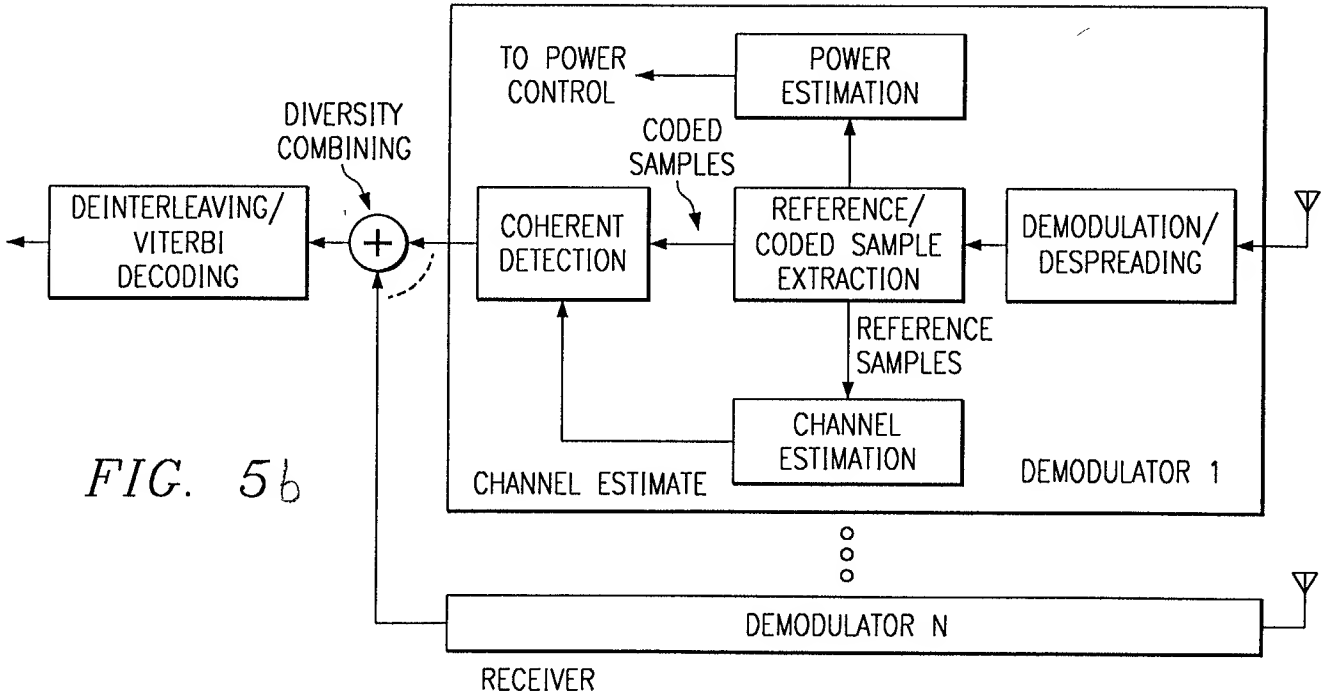

FIG. 5b

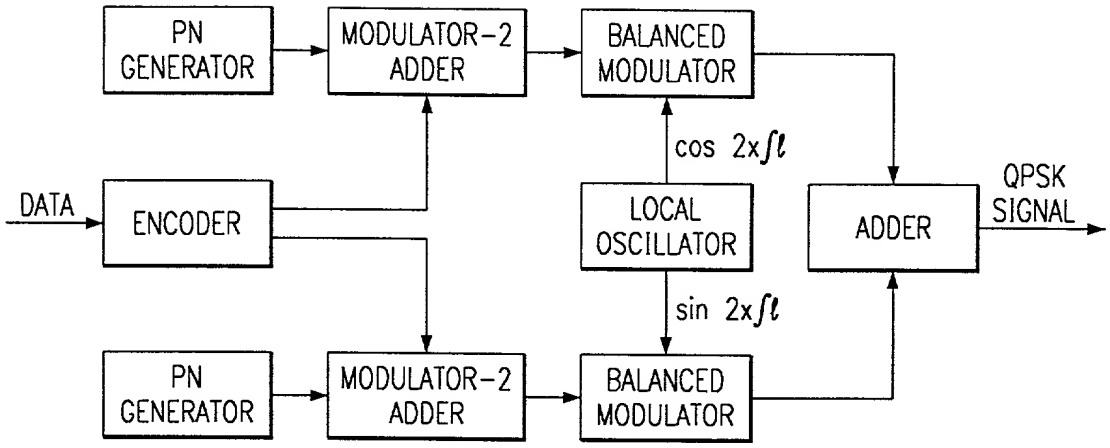
PN GENERATOR
MODULATOR-2 ADDER
BALANCED MODULATOR
cos 2xfl
DATA
ENCODER
LOCAL OSCILLATOR
ADDER
QPSK SIGNAL
sin 2xfl
PN GENERATOR
MODULATOR-2 ADDER
BALANCED MODULATOR

FIG. 3

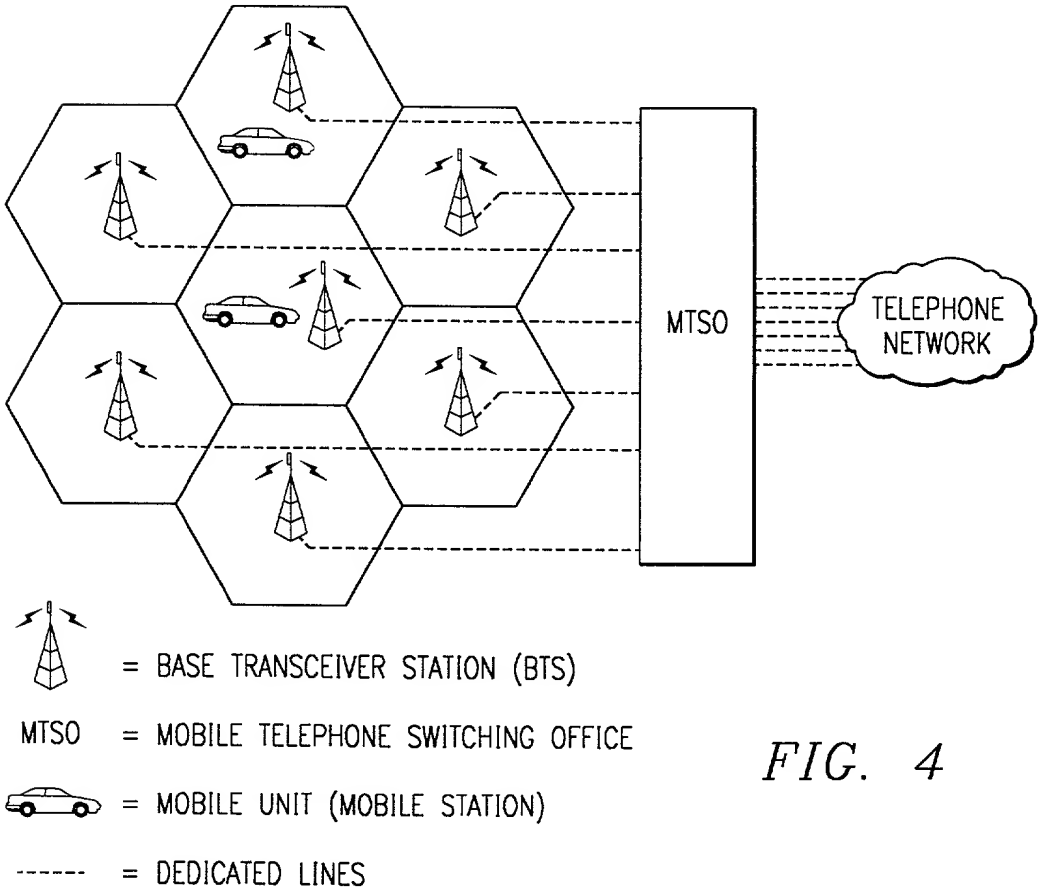
MTSO
TELEPHONE NETWORK
= BASE TRANSCEIVER STATION (BTS)
MTSO = MOBILE TELEPHONE SWITCHING OFFICE
= MOBILE UNIT (MOBILE STATION)
------ = DEDICATED LINES

FIG. 4

SUBSTITUTE SHEET

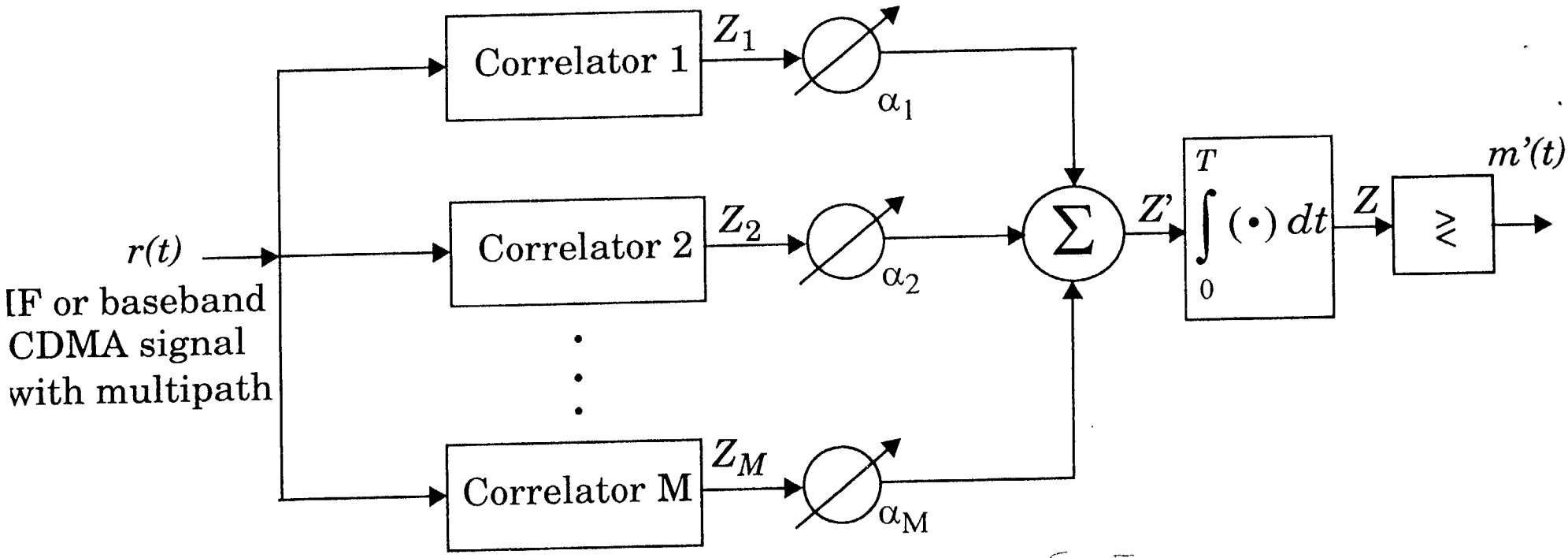

Fig 5a